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ABSTRACT

Sustainability must be integrated into all levels of engineering education, from foundation courses to ongoing projects and research. This report contains the proceedings of the Joint Conference on Engineering Education and Training for Sustainable Development. The objectives of the conference were to define the essential knowledge and skills of the environmentally literate engineer, agree on the fundamental principles of teaching, assist educators in developing curricula, provide examples of initiatives, and establish a network for a continuing exchange of information and experience. The report includes an executive summary, an introduction, the conference program, notes from the opening session, keynote addresses, working groups, plenary presentations of case studies and a closing session, and conference conclusions and recommendations. (WRM)

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World Federation of Engineering Organizations (WFEO)
United Nations Environment Programme (UNEP)
World Business Council for Sustainable Development (WBCSD)
Ecole Nationale des Ponts et Chaussées (ENPC)

joint conference on

Engineering Education and Training for Sustainable Development

Paris, France, 24-26 September 1997

FINAL REPORT

Under the patronage of

Ministère de l'Equipement, du Logement et des Transports, France

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1. EXECUTIVE SUMMARY

This report has been prepared for the sponsors and participants of the conference. The collected papers are held by the UNEP IE Centre in Paris. Some of the material is also available on the Conference web site: http://www.enpc.fr/Eng_conference.

The conference was attended by academics and business representatives from 27 countries. Its objectives were to:

- define the essential knowledge and skills of the environmentally-literate engineer;
- agree on the fundamental principles of teaching;
- assist educators to develop curricula;
- provide examples of initiatives; and
- establish a network for a continuing exchange of information and experience.

Keynote addresses dealt with the unsustainability of the present global situation, the general requirements of industry, the current situation in engineering, and the urgent need for engineers to become knowledgeable about sustainable development.

Working groups were formed to consider

- the needs of employers;
- the teaching of sustainable development;
- teaching tools and support materials; and
- the building of curricula at undergraduate and professional levels.

Plenary sessions received presentations about curricula initiatives, and developed general recommendations.

Key findings

Sustainability must be integrated into engineering education, at all levels from foundation courses to ongoing projects and research. The conference recommends that present engineering curriculum subjects be presented in a sustainable development context. This will require increased cooperation and interaction among governments, industry and education, among universities, engineering organizations and industry, and among academic and industrial leaders.

Many practising engineers currently have no education in sustainable development. Sustainable development should in future be included in both undergraduate and post-graduate courses. Because the transition to sustainable development must be made in the next 20 years, major changes will be required in ongoing education and practising professionals will need retraining.

Teaching should be based on the systems view which, like sustainable development, should be integrated into all instruction. The systems view, and the need for integrated teaching, imply a great

deal of training and retraining within faculties. To speed up this process, the conference recommended a number of actions, including:

- dissemination of research and materials via the Internet;
- setting up a clearing house;
- increased collaboration with industry and engineering practice;
- encouraging the debate about fundamentals;
- benchmarking;
- improved exchange of information; and
- research into sustainable development

Engineering organizations should adopt accreditation policies that require the integration of sustainability in engineering teaching, and encourage the building up of capacity within faculties.

The World Business Council reported that some employers are already testing candidates for environmental capability. This requirement will become more common. Employers represent a powerful agent of change, and they should become proactive in making their needs known to teaching institutions and students.

Recommendations and findings from Working Groups

- governments should develop education policies consistent with sustainable development;
- education policy should encourage and require cooperation and collaboration for trans-disciplinary learning;
- employers should require general environmental literacy of all staff rather than relying on environmental specialists to address key problem;.
- both professional bodies and academics should subscribe to an oath of commitment to sustainable development;
- undergraduate engineering courses should follow the model described in 'Building curricula at the undergraduate level';
- post-graduate environmental engineering should focus on developing environmental skills, not on applying conventional engineering skills to environmental projects;
- all graduate programmes should include at least one course in sustainable development.
- there is a need for 'catch-up' courses and workshops to allow engineering professionals to acquire new skills in environmental subjects such as Environmental Management Systems, monitoring, assessments and audits.

2. INTRODUCTION

The organizing partners of the conference were the United Countries Environment Programme Industry and Environment Centre (UNEP IE), the World Federation of Engineering Organizations (WFEO), the World Business Council for Sustainable Development (WBCSD) and ENPC, the managing partner. The partnership emerged from a shared belief that the reorientation of engineering to meet the needs identified by the United Countries Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, is happening too slowly. The conference examined the ways in which engineering educators could speed up the process.

There is a need for a changed approach in traditional engineering practices, in particular for a development ethic that respects the limited capacity of the planet's resources. Action is made more difficult by a number of factors:

- engineers practise in a wide range of economic, social, and cultural circumstances;
- engineering practice is guided by engineers who have not been trained in environment and sustainable development;
- environment issues are complex and change fast — specialized knowledge is required to deal with some of the implications of sustainable development;
- the increasing demand for diminishing resources, and a deteriorating global environment, have led to increased expectations from technical solutions;
- on average, not much more than 10 percent of time in 10 percent of engineering courses is devoted to environment and sustainable development; and
- the need to retrain practising engineers is as significant as the need to train undergraduates and graduates.

Some initiatives have already been taken. Innovators have adapted existing courses, and a few have even framed new curricula. But major questions remain: what should be taught at undergraduate level to produce engineers trained for new expectations and rapid change? Equally important, what information and training is needed by practising engineers?

The conference was conceived as an interactive event for an invited group of about 60 people, predominantly academics with an interest in engineering and the environment. Industry was also represented. Delegates came from the following countries: Argentina, Australia, Bangladesh, Brazil, Bulgaria, Canada, China, Denmark, Egypt, Ethiopia, France, Germany, Ghana, Hong Kong, Hungary, India, Japan, New Zealand, Malaysia, Morocco, Philippines, Sweden, Trinidad and Tobago, Turkey, the United Kingdom, the United States and Viet Nam.

3. PROGRAMME

The detailed programme can be found in Appendix I.

Conceived as a meeting of experts and innovators who would generate outputs based on their own experience and perceptions, the conference was designed to be interactive and participatory, with the major outputs coming from the working groups. To this end:

- opening, closing and keynote addresses were kept to a minimum;
- the findings of the working groups were presented to and discussed in plenary sessions; and
- the speakers, session chairs and rapporteurs were drawn from the participants.

The first evening featured a poster session, mostly presenting examples of curriculum innovation. Case studies were presented during plenary sessions to illustrate the diverse approaches being used in different regions and in different institutions. Overall, the approach was intended to:

- define the essential knowledge and skills of the environmentally-literate engineer;
- agree on the fundamental principles of teaching;
- help educators develop curricula;
- provide examples of initiatives; and
- establish a network for the continuing exchange of information and experience.

A web site (http://www.enpc.fr/Eng_conference) was set up some months in advance, and used to provide general information and present summaries of keynote addresses, papers about initiatives, a discussion forum and, in the latter stages, detailed information for participants. A month before the conference, with the chairs and co-chairs of the seven working groups determined, the site was used to facilitate discussion about issues and approaches between the working group leaders.

4. OPENING SESSION

M. Jacques Lagardère, Director of ENPC, welcomed delegates, as also did Jean-Pierre Giblin, Director of Scientific and Technological Research of the French Department of Public Works. Ms Jacqueline Aloisi de Larderel, Director of UNEP IE, and Conrado Bauer, President of WFEO, emphasized the interests and concerns of the organizing bodies. An address delivered on behalf of M. Antoine Jeancourt-Galignani, President of Assurances Générales de France (AGF), representing the WBCSD, stressed the importance of environmental literacy in engineering schools. AGF, like other employers, he claimed, needed engineers 'capable of understanding the environmental issues affecting our business'.

5. KEYNOTE ADDRESSES

The three keynote speakers addressed the global context of current and future engineering, the key role of education in this future, the urgent need to create and implement strategies for change, and the needs of employers.

Anthony Cortese, the President of 'Second Nature', an organization devoted to education about sustainability, presented 'Engineering Education for a Sustainable Future'. After showing that the present global situation is demonstrably unsustainable, Mr Cortese outlined the main elements of a sustainable future before discussing the role of higher education. He pointed out that many people believe that society has 20 to 40 years to make the transition to a sustainable path. Higher education is not likely to change its direction far enough or fast enough without strong outside influence. To encourage the educational system to produce the environmentally-aware professionals and specialists needed to lead to a sustainable path, all stakeholders must work with the higher education system..

'The Need for Environmentally-educated Engineers in Industry' was presented by Peter Hindle, Director, Worldwide Technical Policy, of Procter&Gamble. Mr Hindle claimed that there were five key areas for business and industry. Companies must: meet the needs of customers for effective products at a reasonable price. They must also provide products that are safe in manufacture, use and disposal. They must meet the letter and spirit of the law whenever they do business, use resources efficiently, minimize waste, and address the concerns of people by listening and responding constructively. The opportunities for well-rounded and well-educated people, including engineers, are greater than they have ever been before.

David Thom, a vice-president of WFEO, and Chairman of the WFEO Committee on Engineering and Environment, used recent information as a basis for assessment of the current status of engineering education for sustainable development. Sources included a Report to the "Rio+5" Forum of March 1997, and a questionnaire to the 80 national members of WFEO. The engineering profession was thought to number 8 to 10 million practitioners. Much of the work of the profession is in the hands of people who have little environmental training, which makes 'professional development' a matter of extreme importance. The reports indicated that while engineers must become knowledgeable about sustainable development principles and trained in current sustainable development technologies, educational attention to these questions was quite inadequate.

6. WORKING GROUPS

Working group leaders met prior to the conference, and at the end of each day, to exchange experience, discuss issues, consider possible modified briefs and, where necessary, adjust the programme.

First day working groups:

- the needs of employers
- the teaching of sustainable development
- educational tools and support materials

Second day working groups:

- curriculum design for undergraduates
- curriculum design for professionals
- curriculum design for continuing education

Additional working groups formed during the conference.

- future activities related to the conference
- ethics

Working group conclusions

The needs of employers

Employers need general environmental literacy among all their employees rather than a few environmentally-specialized engineers. Pollution prevention and cleaner production, for example, require action by production and design engineers, not by environmental specialists. In effect, the prevention principle requires every engineer to have a good level of environmental literacy. Courses in environmental specialities are not a substitute for this basic need.

It is important to keep higher education informed about industry requirements. Within industry, it is important that education about sustainable development be provided to the work force at all levels, from the Board to the shop floor. There is increasing demand for improved environmental performance from the financial sector, from employers and from supply chains.

The group concluded that there was no widespread need for new 'environmental engineering' courses. Existing courses can be modified to produce environmentally-educated engineers with an appreciation of sustainable development.

Specialized training should be at the professional/graduate level. Many employers would prefer specialist training to be provided in-company and on-the-job.

Teaching sustainable development

There are challenges, constraints and opportunities in every facet of engineering education. The complexity of the education system makes it essential to promote change in many ways, including the formation of new partnerships and networks.

Potential general actions include:

- benchmarking, and comparing the current situation at global and local levels;
- characterizing the attributes of the environmentally-educated engineer, and developing the necessary education processes;
- developing and disseminating resource material;
- creating a directory of sources and mechanisms for establishing contact and exchanges;
- identification of a 'champion' organization on a global scale that could endorse efforts and facilitate fora between industry, academia and society; and
- identify current successful activities and programmes;

Potential individual actions include:

- disseminating information among colleagues, organizing fora for the sharing of views within departments, and (for employees) communicating with company management and professional organizations;
- developing, and implementing strategies aimed at creating a new 'mind set' among colleagues;
- getting sustainable development on the routine faculty agenda;
- developing long-term student projects involving sustainable development;.
- raising sustainable development issues with higher education funding agencies, professional institutions and accreditation bodies;
- reviewing the resources available in terms of people, time, finance and facilities;
- finding ways of making the university environment sustainable — by, for example, developing real examples in teaching material and developing sustainable development curricula;
- planning a university project on the integration of preventative environmental strategies in technical courses;
- specifying the need for qualifications related to sustainable development in future advertising for staff;
- alerting senior institutions to environmental issues that should be included in curricula; and
- including environmental concerns into criteria for engineering awards.

Potential actions that could be carried out by groups or individuals if assistance were available:

- expanding existing web site databases to include more case studies on industry;
- developing tools for evaluating and benchmarking courses that have changed attitudes or developed new skills;
- helping to develop dialogue between academic, industry and government leaders to promote demand for environmentally-literate engineers;
- recommending to the Commission for Sustainable Development that the education community be recognized as a major group in Agenda 21; and

- contributing to a regional support group for academics trying to integrate sustainable development into courses.

Educational tools and support materials

The teaching and learning principles on which to base the integration of sustainable development into engineering education should include:

- involvement of 'head, heart and hands' in collaborative schemes;
- a learner-centred approach which follows the learner in contrast to driving the learner;
- a diversity of different approaches to help students understand;
- feed back systems and structures that are effective, appropriate and self-consistent; and
- leading by example.

The most effective way to integrate sustainable development is through student-centred learning, problem-based approaches, case studies, story telling and anecdotes, role playing and first-hand learning in, for example, field trips. The pivotal role of the lecturer was discussed, and concern was expressed about the lack of teacher training among both older and younger faculty members. The use of 'faculty survival kits' (in use in some institutions) was considered valuable. These should include concepts of sustainable management and development. Existing kits should be made generally available.

Building curricula at the undergraduate level

As their higher level of skills allows them to fill environmental specialist roles as well as traditional engineering functions, graduates from existing 'environmental engineering' courses will fulfil a valuable role in the medium term, until sustainable development is fully integrated into engineering education. Full integration will require significant changes in both the structure and presentation of undergraduate courses.

It was concluded that the future of engineering does not lie with the four traditional areas of engineering — civil, mechanical, chemical and electrical — but will embrace a new systems approach (see table below).

Old	*New*
Physical Sciences mathematics physics mechanics chemistry logic	**Modelling** analytical computational conceptual systems
Natural sciences biology geology	**Natural systems** biological cycles and systems geophysical cycles and systems
Engineering materials introduction to properties, use and production	**Engineering materials** introduction to properties, use and production
Communication written and oral presentations	**Communication** negotiation graphics
	Strategic solutions (introduction) cleaner production and life cycle management environmental management systems and tools resource efficiency environmental design

Note. The template on the right is for all engineering courses. It could appeal to university administrators due to the 'economies of scale' that result from the fact that it can be taught in larger classes. It also has also an educational appeal because different disciplines will have the opportunity to share sustainability within their own engineering courses.

There was considerable support for networking and coordination of undergraduate curricula, especially in the early years of a degree. In addition to the invaluable benchmarking of qualifications that this would provide for industry and the professions, this would give greater opportunity for (and acceptance of) transferring students.

Building curricula at the post-graduate level

Not all countries have a sustainable development component in post-graduate programmes in environmental engineering. Currently, too many post-graduates in environmental engineering finish their course without adequate skills in environmental assessment, analysis and management. Post-graduate environmental engineering should focus on environmental skills, not on conventional engineering skills applied to environmental projects, such as the design of wastewater treatment plants. The following are important components of the new approach:

- emphasis on pro-active solutions;
- emphasis on social and cultural aspects of engineering projects;
- minimizing environmental impacts while meeting needs; and
- the multidisciplinary nature of environmental and sustainability problems.

Retraining all faculty members and forming new industry/university partnerships will be important in implementing the new approach.

The *Training Needs Analysis* of the Exxon Corporation is an example of a useful guide for the development of graduate programmes. The following table illustrates some of the action and training needs required to produce environmentally-aware engineers.

Employee group	***Action required***	***Training needed for***
Engineer	Follow environmental design standards	Understanding environmental concerns
	Use existing skills to meet new goals	Contributions to company policy, goals and programme
	Identify improvement criteria in engineering standards	Including environmental opportunities
	technologies	Assessment of emerging
	as environmental issues develop	Motivation to change procedures further

All graduate programmes in engineering, (other than in environmental engineering itself, where this is already integrated) should have at least one integrated course in sustainable development. Graduate students should be able to opt for research in sustainable development. Such research is most important at international, national and local levels. It is recommended that both government and private funding agencies give priority to research into sustainable development, and that collaboration with industry be promoted.

Building curricula for continuing professional development

There are three important issues to consider: people in work, need and opportunities for continuing education, and the question of how to deliver. Education should be appropriate to all members of a work team, and not be addressed to engineers alone.

There is a need for 'catch-up' courses and workshops to allow engineering professionals to acquire new skills in environmental subjects such as Environmental Management Systems, monitoring, assessments and audits.

The need at this stage is for basic information but this will change. Different sectors require specific information in relation to the application of general concepts. Opportunities for continuing education are often limited, perhaps to two or three days a year, and in 'own time'.

Delivery needs to be in the form of short, intensive packages within a sustainable development framework. General teaching on sustainable development is not appropriate. Delivery can be in the form of self-learning material from providers such as conferences on topics including sustainable development, professional organization section meetings, and individual groups within technical interest groups.

The following is recommended:

- continuing dialogue about education needs between providers, industry and professional organizations;
- 'champions" of sustainable development education within universities and professional organizations;
- industry to provide case studies for teaching purposes as well as information in the form of newsletters, for example;
- continuing discussion of the technology regulatory framework (including education) between government and professional organizations; and
- the advocacy of sustainable development (including appropriate education) by the large resource represented by professional engineers — an activity that will enhance the status of engineering.

Future activities related to the conference objectives

One key message was the importance of sustainable development principles in all activities related to society, education and industry. Another key message was the importance of the systems view. Dissemination could also be helped by viewing the process as an interaction between three elements: government, industry and university.

Regional conferences would be a logical next step in carrying forward this work.

Ethics

With a widening understanding of the key role of technology, and the limitations of a technology-only approach, in the movement towards sustainable development, the ethical position of engineers assumes increasing importance, as does the teaching of ethics.

Several engineering bodies (such as WFEO, FIDIC, IPENZ and ASCE) have codes of ethics and guidelines that refer to sustainable development. Industry has a 'Responsible care®' programme representing a declaration of moral responsibility for outcomes during the life cycle of a product. An increasing number of chief executives in industry are now treating sustainable development as a key goal for their businesses. This will eventually be translated into recruitment practices within these companies.

The proposal to have an 'oath of commitment' for both engineering individuals and professional bodies is endorsed in principle, and the following actions are recommended:

- the concept of an environmental oath be promoted by WFEO among national and regional professional bodies;
- WFEO solicits drafts of a proposed oath from national and regional bodies; and
- a draft be prepared and circulated, and subsequently proposed for adoption by a WFEO General Assembly.

7. PLENARY PRESENTATIONS OF CASE STUDIES

Two plenary sessions were devoted to presentations on current initiatives, firstly by geographical area and secondly by institution.

United Kingdom

Dr Shirley Ali Khan, Director of the Forum for the Future's HE 21 Project, discussed the UK report *Environmental Responsibility: an Agenda for Further and Higher Education*, published in 1993. The key recommendation was that 'after consultation with its staff and students, every higher and further education institution should formally adopt and publicise, by the beginning of the academic year 1994/5, a comprehensive environmental policy statement, together with an action plan for its implementation'. Twenty-six other recommendations were targeted at government, further and higher education (FHE) institutions, funding councils and professional bodies. Dr Ali Khan was commissioned to carry a review within three years.

This revealed that most of the institutions targeted in the 1993 report had demonstrated 'considerable indifference' to its recommendations. Only 114 of 756 FHE institutions claimed to have environmental policies in place. Where policies existed, implementation was generally at an early stage with most progress being made on the good housekeeping side, particularly in areas associated with obvious cost savings, such as energy efficiency or where the 'green' ticket could help institutions introduce unpopular measures such as car parking charges. Little progress was found in areas such as purchasing.

Only 17 FHE respondents claimed to have set out in general terms what all their students needed to learn in order to be able to take account of sustainable development in their work and daily lives. Of these, fewer than six are making significant progress.

The Review included six key recommendations.

- enabling responsible global citizenship should be recognized as a core business of learning institutions and a legitimate purpose of life-long learning;
- funds should be made available to establish a national programme to support the FHE response to the challenge of sustainable development;
- within three years all FHE institutions should be either accredited to, or committed to becoming accredited to, a nationally- or internationally-recognized environmental management systems standard, such as the Eco Management and Audit Scheme;
- within three years all FHE institutions should have developed the capacity to provide all students with the opportunity to develop defined levels of competence relating to responsible global citizenship;
- those responsible for defining national standards relating to industrial and professional practice should ensure that appropriate reference is made to sustainable development issues;
- within three years all funding councils should introduce a mechanism for linking environmental performance to the allocation of funds, for example by introducing environmental criteria into existing quality assessment and inspection procedures.

United States

Professor Jorge Vanegas of the Georgia Institute of Technology presented the new curriculum initiatives of his institute. In 1993, the College of Engineering at Georgia Tech., in partnership with the Centre for Sustainable Technology (CST), launched an institute-wide project funded by the General Electric (GE) Fund to develop a new curriculum in sustainable development and technology. The results serve as a model of how an engineering curriculum can fulfil the demands of tomorrow rather than simply meeting the needs of today.

A primary achievement has been to develop a three-course sequence in sustainable development and technology: Introduction to Sustainable Development; Case Studies in Sustainable Development; and Designing Sustainable Engineering Systems.

The curriculum has been designed to develop student's skills in dealing with problems in sustainable development and technology. The courses provide students with a broad overview of the concept of sustainability. The case study and design courses provide students with the opportunity to use decision-making skills in applying the concepts of sustainability.

The greatest impact of the GE Fund project has been the fundamental changes occurring across the entire campus, from research, to campus ecology, to curriculum development and delivery. Georgia Tech. is committed to creating a sustainable society and to educating faculty, staff and students on the concepts and principles of sustainability.

The curriculum is changing. Not only are classes offered that focus primarily on sustainability but the principles of sustainability are permeating into both graduate and undergraduate courses. For example:

- students of public policy are offered sustainable systems, world food, population and development, sustainable metro ecosystems, sustainable urban design, and economics of sustainability;
- the College of Architecture offers a Lab for Sustainable Design and classes in Environmental Impact Assessment;
- mechanical engineering students can enrol in environmentally-conscious design and manufacturing, and can participate in hands-on projects in Atlanta communities;
- earth and atmospheric sciences provide classes in how to build a habitable planet and global change;
- a class on economics and environmental policy is targeted at students from public policy, economics and city planning.

Key subject areas taught across the curriculum, such as ethics and humanity, thermodynamics and complexity, also expose students to sustainability.

Importantly, learning opportunities are not only available through credit courses. For the first time, Georgia Tech's 'Leaders for a Sustainable Society' programme will be offered during Earth Week to students, faculty and staff.

All of the recommendations of the Campus Master Plan are founded on one central principle: sustainability. The creation of a sustainable campus environment is an objective of the Strategic Plan of the Institute. As such, the Master Plan considers resource efficiency in transportation, building design and maintenance, restores green space, and creates an environment which encourages collaboration among researchers interested in issues relevant to a sustainable society.

Sustainability is permeating the research agenda at Georgia Tech. through initiatives in urban ecology and industrial ecology. The research agenda in industrial ecology aims to understand the interactions among firms in industrial production systems and their interactions with their economic, social and natural environment. Students and faculty across the campus learn about industrial ecology from the perspective of their discipline and others in the Industrial Ecology Study Group.

The UNEP IE Cleaner Production Inventory

Professor Michael Jorgensen, Department of Technology and Social Sciences, Technical University of Denmark, outlined the findings of a questionnaire on cleaner production education and training that had been answered by 139 institutions worldwide, mainly European universities. The main conclusions were:

- the number of specialized cleaner production courses (such as life cycle assessment) is growing;
- technical courses which integrate preventive environmental considerations are increasing; and
- some masters curricula on cleaner production and environmental management have been created; and
- continuing education, corporate in-house training, and consultancy are also being introduced.

Cleaner production requires new qualifications for all kinds of engineers, and changes in all curricula, because prevention and minimization requires not just add-on changes but changes in product design, choice of chemicals and processes, maintenance, inventory management and working routines.

Three different strategies for integrating cleaner production into curricula were reported:

- integration into existing environmental course modules;
- integration into existing technical course modules; and
- development of new course modules on cleaner production.

The South-east Asia Pacific Region

Professor David Elms, of Canterbury University, New Zealand, a former President of the Association of Engineering Educators of South-east Asia and the Pacific (AEESEAP), outlined the situation in the SEAP Region.

Education in environment and sustainable development is currently neither well nor widely executed. There are a few enthusiastic people but they tend to be isolated, especially in Asian countries. Nonetheless, there have been good specific initiatives such as the development of curricula guidelines in Australia. The AEESEAP has been encouraging environmentally-educated engineering through conferences, and with a student prize.

UNITEC, New Zealand

Professor John Buckeridge outlined the influence of the New Zealand Resource Management Act on engineering education, particularly with the new BE course at UNITEC. The Act, which was passed in 1991, legislates an obligation to sustainable management. Undergraduates are being given the mental tools to conceptualize the environments they are producing, and are likely to plan. In the programme, students are exposed to a broad appreciation of biological, climatological, geological and social processes, and to management. In implementing this through a systems approach, educators strive to produce a learning environment that integrates an earlier engineering 'pragmatism' with a new environmental sensitivity.

An Internet Course on Sustainable Development

Dr Fiona Crofton, Principal of the ORCAD Group, focused on the Internet. She provided:

- a brief overview of the current and potential use of the Internet — both as a resource and as a vehicle for education, information exchange, interaction, data analysis and the building of 'virtual community';

- a 'tour' of ORCAD's web-based course and materials on sustainable development and engineering.(at www.sustainability.com/orcad) which has been designed for use as a full course (undergraduate and professional development versions) or as support materials for use in existing courses; and

- an outline of the work in progress and the future potential of the Internet for furthering the understanding of sustainable development.

8. CONCLUSIONS AND RECOMMENDATIONS

The working groups were asked to develop action proposals for individuals and for the organizing partners of the conference. These proposals were reviewed by a plenary session and are summarized below.

General recommendations

1. There is a need to create a broad international partnership to give leadership, stimulate further curriculum change, and monitor progress in sustainable development education. This partnership should:

- encourage business to articulate its need for environmentally-literate engineers;
- support and publicize model courses and training materials;
- encourage international education bodies to promote environmental literacy in professional education;
- promote an environmental and sustainability ethic in engineering;
- sponsor an office to serve as a clearing house;
- assist other organizations with capacity building and information exchange; and
- consider actions such as the setting up of an Internet Conference for the exchange of experience, in preparation for a specialized international seminar.

2. At the national level, there should be action to:

- define the profile of an environmentally-literate engineer;
- review curriculum accreditation policies;
- make faculties more receptive to change on sustainable development education issues; and
- increase the number and effectiveness of individuals working towards change.

3. A number of catalytic actions were recommended:

- regional train-the-trainers workshops involving several national bodies;
- dialogue with key accreditation bodies;
- dialogue and action with major employers and education bodies;
- publication of model courses and case studies;
- a web-based network for information exchange;
- encouragement of universities and colleges to act on sustainable development, and obtain EMS and ISO accreditation;
- lectures from external resource persons; and
- internships for students in companies.

4. Special support is needed for developing countries.

Recommendations for UNEP

1. Monitor progress of the programme to increase environmental literacy.

2. Disseminate information about the tools (such as environmental management systems, life cycle analysis, environmental impact assessments and cleaner production) that are needed in sustainable engineering practice, and which need to be taught more widely.

3. Provide special support for developing countries.

4. Support and encourage interfacing and networking between industry and academia.

Recommendations for WFEO

1. Develop conference outreach through all possible means, including publications, proceedings, setting up networks and web sites, sponsoring workshops, and ensuring that environmental education is a prominent feature of WFEO events. The WFEO should develop appropriate policies on education and accreditation, and organize regional conferences to expand the work of this conference.

2. Produce a set of principles on sustainability for engineers which would be appropriate at global, regional and local levels. Specify ways of translating these principles into engineering practice.

3. Continue the debate on sustainable development principles via bulletins and newsletters, and create national working groups on this topic.

4. Develop an environmental oath for engineering, and promote its general acceptance.

5. Collect information on engineering curricula, and establish an on-going monitoring, survey and reporting mechanism.

6. Benchmark the status of engineering education now, so that a basis for comparison is available in the future.

7. Disseminate information on the current state of development of environmental management systems, life cycle analysis, environmental impact assessments and cleaner production.

8. Encourage senior engineers from industry to lecture at universities and lead seminars.

9. Encourage student-led conferences on sustainable development in engineering education.

10. Encourage engineering organizations to help in teaching sustainability within primary and secondary education.

Recommendations for WBCSD

1. Develop partnerships with academic institutions through exchange of personnel, sharing best practice, research contracts and case studies.

2. Continue the dialogue on sustainable development in engineering education within WBCSD organizations.

3. Consult members on sustainable development criteria for recruitment, and then monitor and publicize suitable recruitment policies. Consider the possibility of an oath as a prerequisite for employment.

4. Demonstrate commitment to sustainable development in local activities through training, provision of materials and sponsorship.

5. Ensure that educators have information about, and understand the policies and practices of companies in relation to:

- financial and environmental indicators on sustainable development in annual reports;
- the implementation of sustainable development principles in industrial supply chains; and
- recruitment criteria on sustainable development and environmental literacy.

6. Support continuing education and in-house training in sustainable development for all staff.

7. Publish a book of case studies, and develop a list of recommended books and educational materials on sustainable development.

Recommendations for academic institutions

1. Review and change undergraduate and post-graduate curricula to integrate sustainable development in education courses.

2. Ensure that all graduate programmes are interdisciplinary and that there is at least one integrated course on sustainable development. Graduate students should be able to opt for research in sustainable development.

3. Provide teaching materials for integrated courses and support faculty staff interested in promoting these courses.

4. Develop and disseminate curriculum material with other faculties, universities and professional bodies.

5. Explain to prospective students the faculty policy on environment and sustainable development, and its relevance to the courses being offered.

6. Initiate research and development projects in partnership with industry, and encourage long-term research projects for cleaner technologies in collaboration with industry.

Action by individuals

1. Disseminate information amongst colleagues, organize fora for the sharing of views within departments, and communicate with company management and professional organizations.

2. Initiate a dialogue to build a new 'mind-set' among colleagues.

3. Get sustainable development on to the routine agenda of organizational meetings and reviews.

5. Raise sustainable development issues with higher education funding agencies and professional institutions and accreditation bodies.

6. Find ways to make the university environment sustainable. Initiate or participate in 'greening the university' projects.

7. Develop teaching materials and courses that include sustainable development.

8. Plan a university project on integrating preventive environmental issues and strategies in technical courses.

9. Incorporate environmental concerns into criteria for engineering awards.

9. CLOSING SESSION

M. Jacques Lagardère welcomed Mme Dominique Voynet, the French Minister of Regional Planning and Environment. He stressed the importance of the results of the conference for the ENPC and thanked the participants for their work.

M. Bruno Tassin, ENPC coordinator within the organizing partnership, presented a summary of the recommendations and commitments.

Mr David Thom, speaking on behalf of UNEP IE, WBCSD and WFEO, thanked the ENPC for providing the venue and the participants for their enthusiasm.

The closing address was delivered by Mme Voynet, who stressed the global importance of the conference as a response to the challenges posed by sustainable development. She noted that for business, sustainable development is not only a set of compulsory duties but also an enormous challenge and opportunity. The aim of engineering education included more than ensuring technical mastery and efficiency. It was also to help engineers, in their professional life, have fruitful discussions with other disciplines, consumers and citizens. Such a dialogue was essential to the creation of a sustainable society.

10. APPENDICES

I. The detailed programme

Tuesday 23 September

15.0 Meeting of working party leaders

18.00-20.00 Welcoming reception

Wednesday 24 September

08.30 Registration

09.00 Opening ceremony:
M Jacques Lagardère, Director ENPC
M Jean-Pierre Giblin, Ministère de l'équipement des transports et du logement
Mme Jacqueline Aloisi de Larderel, Director UNEP IE
Mr Conrado Bauer, President WFEO
M Antoine Jeancourt-Galignani, President des Assurances Générales de France

Keynote presentations

10.00 Mr Anthony Cortese, President, Second Nature
Engineering Education for a Sustainable Future

10.30 Mr Peter Hindle, Director, Worldwide Technical Policy, Procter&Gamble
The Need for Environmentally-educated Engineers in Industry

11.30 Mr David Thom, President, WFEO Committee on Engineering and Environment
Where are we now? Key elements for decision and action

14.00 ***Parallel working groups***
The needs of employers
Chair: Dr Hamid Farabi, Faculty of Engineering, The University of the West Indies, Trinidad and Tobago.

Teaching sustainable development
Chairs: Samia Saad, Visiting Professor at the American University in Cairo
Professor Jorge Vanegas, Georgia Institute of Technology, United States

Educational tools and support materials
Chair: Dr Fiona Crofton, ORCAD Group Inc., Canada

17.30 Working group leaders debrief and synthesis

18.00-20.00 Poster session: case studies of educational tools and training

Thursday 25 September

8.30-9.30 Reorientation and plenary with reports from previous afternoon sessions

9.30-10.45 Forum and break-out groups: Reflections and Action Agendas

11.15-12.00 Report back

12.00-13.00 *Plenary*: ***case studies***
Dr Shirley Ali Khan, Forum for the Future, United Kingdom
The UK Toyne Report
Professor Jorge Vanegas, Georgia Tech., United States
The United States and Georgia Tech

Professor Michael Sogaard Jorgensen, Technical University of Denmark
The UNEP IE Cleaner Production Training Inventory.

Professor David Elms, University of Canterbury, New Zealand
The South East Asia Pacific Region

14.30-17.30 ***Parallel working groups: building curricula***
Undergraduate level
Chair: Mr Desta Mebratu, Research Associate, Lund University, Sweden

Professional level
Chair: Professor Al Taweel, Dalhousie University, Halifax, Canada

Continuing education
Chair: Mr Charles Duff, WBCSD, United Kingdom

Future activities related to the conference
Chair: Dr Fiona Crofton, the ORCAD Group Inc., Canada

Ethics
Chair: Professor Osama El-Kholy, Emeritus Professor Cairo University

16.45-18.00 Working group leaders debrief and synthesis

Friday 26 September

8.30-9.30 Overview and plenary: reports from Thursday afternoon sessions

9.30-11.00 Forum and break-out groups: Recommendations Part 1

11.15-12.00 Report back

12.00-13.00 *Plenary: case studies*
Professor Jorge Vanegas, Georgia Tech., United States
Georgia Tech. and the GE Fund Project

Professor J. Buckeridge
The Influence of the New Zealand Resource Management Act on the new B.E. degree at UNITEC

Dr Fiona Crofton, ORCAD Group Inc., Canada
Internet Education: Engineering and Sustainable Development.

14.30-16.30 Forum and break-out groups: Recommendations Part 2

17.00 Closing session

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III Web sites

The conference site
http://www.enpc.fr/Eng_conference
The web site for this conference, presenting a description of the conference, information about the sponsors, keynote papers, and this report.

Sustainability: general
http://iisd.ca/
The International Institute for Sustainable Development. A comprehensive range of information on sustainable development.

Test of environmental literacy
http://www.wbcsd.ch/foundation
A test of environmental literacy, *The Sustainable Business Challenge* of the WBCSD. A brief about the minimum level of knowledge expected by business leaders, followed by an exam.

Curricula
http://www.2nature.org
Second Nature is a US non-profit organization working to help tertiary educators with integration of environmentally-sustainable development into tertiary education. The site provides information about programmes, services, resources and information exchange. Assistance for curricula development includes more than 250 syllabi and reading lists.

Internet course on sustainable development
http://www.sustainability.com/orcad/sdeng
The first web-based introductory course on sustainable development and engineers. The materials include topic-specific modules and full courses. All materials, approaches and learning activities are tailored to fit the needs of specific groups.

Engineering web sites
http://www.WENet.org.
The World Engineering network.

http://sunsite.anu.edu.au/feiseap
The network of the Federation of Engineering Organizations of South East Asia and the Pacific (FEISEAP).

http://wwwparis.enpc.fr/~michel-j/WFEO/home.html
The web site of the World Federation of Engineering Organizations.

Cleaner production
http://www.unepie.org/
The site of UNEP IE, this also deals with Industrial Pollution Prevention, Environmental Technology Assessment, Energy Efficiency, and Ozone Action. Under Cleaner Production, you will find information about activities, working groups, national cleaner production centres, publications and the International Cleaner Production Information Clearing House (the ICPIC database which includes, among many other things, many case studies).

IV. The WBCSD survey

The WBCSD has surveyed its members to discover what skills they seek in newly graduated applicants for jobs in their businesses:

One-third of the members of the WBCSD provided responses, from countries such as Japan, Norway, Portugal, the United States, New Zealand, Italy and the United Kingdom. The replies covered many industrial sectors including banking, insurance, forest products, petrochemicals, the motor industry, electronics and the food industry.

The replies were received from 33 companies, with collective annual sales of US$400 000 million, which recruit more than 4000 graduates year.

All responses said that the environment had grown in importance as a business issue over the past five years. All expected the environment to grow in importance over the next five tears (apart from those who said it was already of paramount importance). And all respondents reported that the level of an applicant's environmental awareness would become more important in the selection process.

The main conclusions drawn from the survey were that:

- a good academic record, good levels of interpersonal and communication skills, and work experience, are important selection criteria;
- an appreciation by job applicants of the links between business and the environment has become important for many employers — one-third of the sample are already testing candidates for evidence of this awareness.

The WBSCD survey resulted in a message for higher education:

'You must ensure that your students, whatever their field of study or their job aspirations — modern languages as well as engineering, sales and accounting as well as plant management — are provided with this awareness and competence. If you do not, you will be jeopardizing their chances of recruitment by the very companies which are most likely to be able to offer them a productive future. These are the companies which, thanks to the strategic thinking they have already undertaken, have identified the competitive advantages to be won from dealing creatively with the unavoidable challenge of generating a sustainable future for their business.'

V. The WFEO survey

WFEO joined forces with FIDIC (the International Federation of Consulting Engineers), and UATI (the International Union of Technical Associations) to form the World Engineering Partnership for Sustainable Development in 1992. In 1997, this partnership submitted a report, *The Engineers' Response to Sustainable Development* to the Rio + 5 Forum, one of the reviews to test progress on Agenda 21, after UNCED in 1992. Following this report, a questionnaire was circulated to national members of WFEO in an endeavour to provide an improved benchmark for engineering progress. At the end of February, 1998, 18 responses (of approximately 80) had been received. These included 7 from developed countries, and 11 from developing countries.

The questions and responses were as follows:

How many engineering degree programmes do you have in your country?
Answers ranged from a small number (generally for developing countries) to a large number for developed countries.

Are there any BE (Environmental) programmes or similar?
Twelve countries reported BE (Environmental) programmes. Two of the six countries with no environmental engineering programmes were developed countries.

Does teaching of sustainability or the environment feature in engineering courses?
Thirteen countries reported that teaching of sustainability or the environment featured in engineering courses. One developed country indicated no such teaching, and one developed country reported little teaching.

If 'yes', what percentage of engineering courses provide for it?
Only ten countries attempted estimates: six at 10 per cent, one at 20 per cent, and the rest at 5 per cent.

If 'yes', what percentage of course time is allocated?
Only nine countries attempted an estimate: 3 at 5 per cent, 3 at 10 per cent, and 3 more than 10 per cent.

Is any research into engineering and sustainability carried out within your universities?
Ten countries reported that research into engineering and sustainability was carried out.

Conclusion: with responses from only 18 countries, the information can be considered to be indicative only. However, the survey does not indicate a strong or consistent approach to the environment and sustainable development in engineering education or that, on a country average, much more than 10 per cent of time in 10 per cent of courses is devoted to these aspects.

VI. Conference evaluation

At the end of the conference feedback forms were provided. Respondents were asked to reply to six questions, with a rating ranging from 1 (very poor), to 5 (excellent). Twenty-two of 64 respondents (34 per cent) replied. The questions and responses were as follows:

What were your expectations/objectives in attending this event? Were they met?
Eight (effectively out of 17 or 47 per cent, as five did not assess whether objectives had been met) indicated that expectations had been met, and one that expectations had been exceeded. Nine (effectively out of 17 or 53 per cent) indicated that objectives had been partially met.

What were the strengths of this event (or what did you like)?
Major positive features most often mentioned were:

- informality and enthusiasm
- good mix of international participants
- an outstanding facilitator
- diversity and opinions brought from all corners of the world
- participative nature of the conference
- good opportunity to meet people, and hear of new initiatives and actions
- meticulous arrangement and time management
- the conference was a working event not just a series of presented papers.

What were the weaknesses of this event (or what did you dislike)?
Major negative features most often mentioned were:

- there was too little time
- there was a lack of organization and clarity about details
- the objectives could have been better focussed early on
- French interpreters would have been useful
- most of the recommendations were too general and vague
- no government representatives and not enough business representation
- there were too many small group discussions
- the objectives were too ambitious for the time available

How did you rate the event overall?
Individual ratings were: 3, 4, 4, 3, 3, 4, 5, 5, 3.5, 3, 3, 3, 4, 4, 4, 3, 4, 5, 4.5, 4.5, 3, 3. Total, 82.5. Average = 3.75

Do you have any suggestions for improvement?
Answers included:

- extend the conference to one week
- a continuing effort to work on this important issue into the future
- working group leaders need better preparation and instruction as to what they need to do
- a long break in the middle of the day to get fresh air and exercise
- a smaller number of concrete and feasible actions with a definite plan for delivery.

Any other comments?

- 'Tell me and I forget, show me and I remember'
- a worthwhile meeting overall even though disappointing in some details
- participatory nature of the conference highly appreciated
- every participant could be asked to send feedback on the status of implementation of the recommendations at the end of one year
- happy to support this initiative but clear results must be demonstrated
- report please in 1999 so we can review progress and continue planning to take appropriate action.

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